Challenges for effective and realistic 5G OTA testing

March 2019

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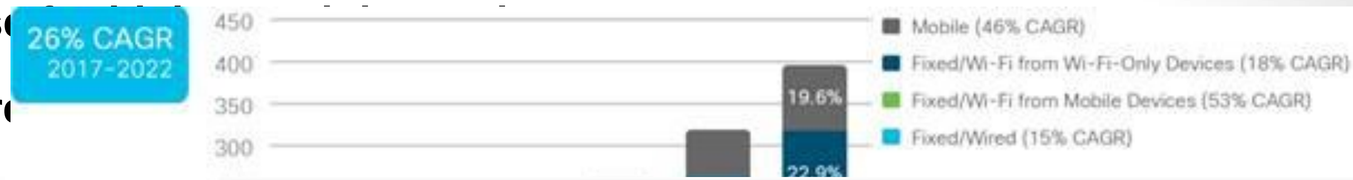
Región de Murcia

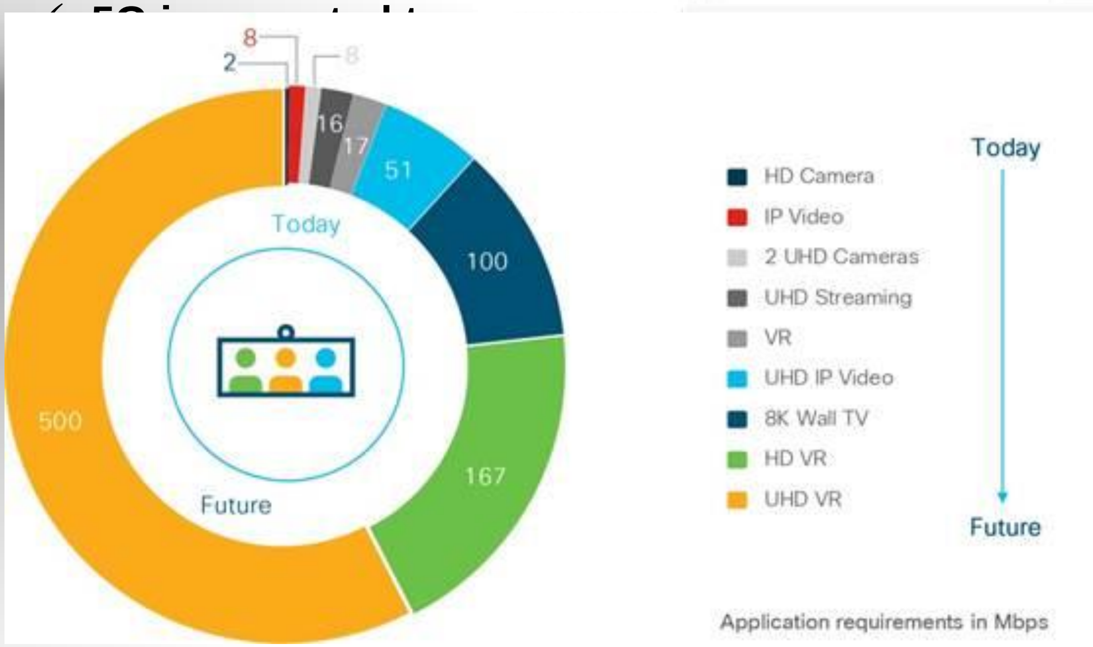
f SéNeCa(+)
Agencia de Ciencia y Tecnología
Región de Murcia

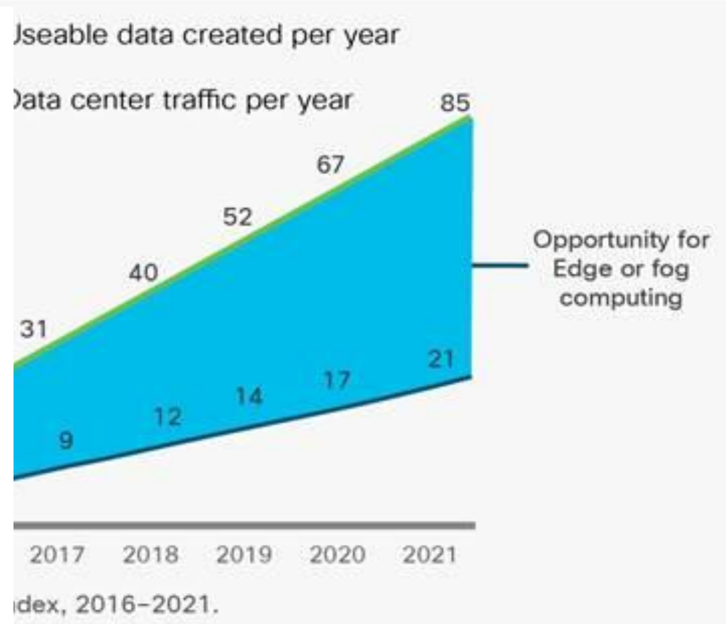
* Research work funded by the Autonomous Region of Murcia, in Spain, through the 20517/PDC/18 Fundación Séneca project

01 Some 5G numbers

- ✓ **670% Global Mobile Traffic growth from 2016 to 2021**
- ✓ **Significant increas**
- ✓ **Impressive user-cr**
- ✓ **5G is expected t**







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02 5G OTA Test Methods

FR1	410 MHz – 7125 MHz
FR2	24250 MHz – 52600 MHz

DUT Antenna Configuration	Direct Far Field (DFF)	Indirect Far Field (IFF)	Near Field to Far field transform (NFTF)	Near field without Transform (NFWOTF)	Reverberation Chamber (RC)
1	Yes	Yes	Yes	Yes	Yes
2	Yes	Yes	Yes	Yes	Yes
3	Not yet	Yes	Not yet	Not yet	Not yet

DFF and IFF: Approved in RAN4 [3GPP TR 38.810 v2.0.0]

NFTF: Approved in RAN4 [3GPP TR 38.810 v2.1.0]

NFWOTF and RC: Not approved in RAN4 [3GPP TR 38.810] yet for variety of reasons

DUT Antenna Configuration	Description
1	Maximum one antenna panel with D ≤ 5 cm active at any one time
2	More than one antenna panel D ≤ 5 cm without phase coherence between panels active at any one time
3	Any phase coherent antenna panel of any size (e.g. sparse array)

Conducted

OTA
(TRP/TRS/
Spurious/
MIMO)

OTA

Conducted testing

OTA measurements in Far Field *

Re-use LTE UE
Testing methodology

7.125 GHz

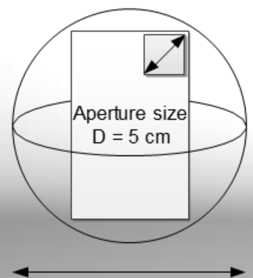
24.25 GHz

* Note: Alternative near field methods are not precluded

02 5G OTA Test Methods

DUT Antenna Configuration 1

Applicability to single aperture, D = 5 cm

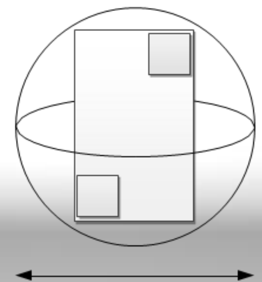


Quiet Zone diameter = 15 cm

- A DUT with <u>single</u> radiating aperture
  - The aperture has max dimension of D = 5 cm
  - The aperture can be placed anywhere within the QZ
- In this situation, the following requirement on test zone quality applies:
  - A magnitude requirement on test zone quality is sufficient.

DUT Antenna Configuration 2

Applicability to multiple non-coherent apertures, D = 5 cm

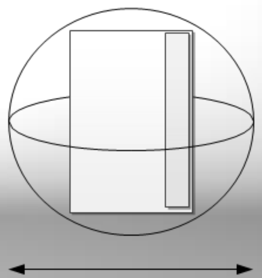


Quiet Zone diameter = 15 cm

- A DUT with <u>multiple</u> <u>non-coherent</u> radiating apertures
  - Each aperture has max dimension of D = 5 cm
  - Each aperture has its own independent receiver chain
  - Apertures can be placed anywhere within the QZ
- In this situation, the following requirement on test zone quality applies:
  - A magnitude requirement on test zone quality is sufficient.

DUT Antenna Configuration 3

Applicability to single aperture, D = 15 cm



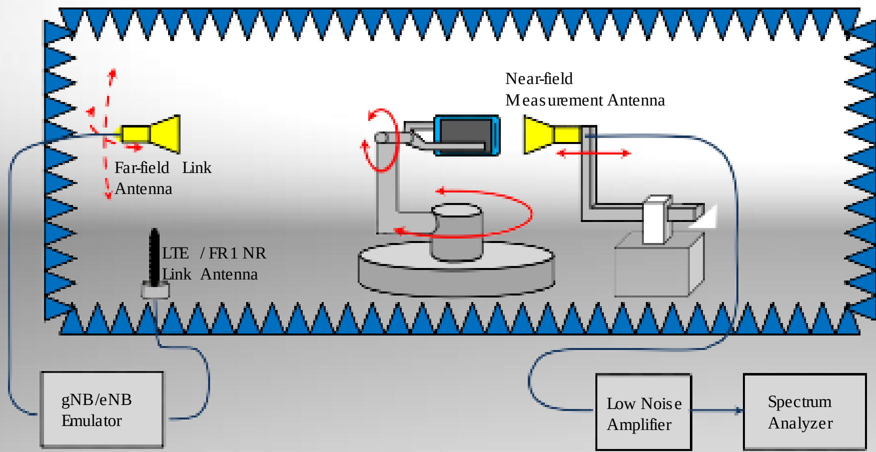
Quiet Zone diameter = 15 cm

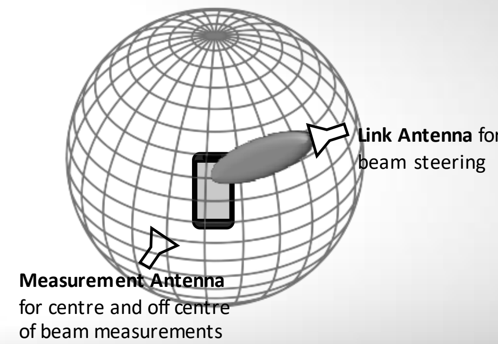
- A DUT with a single coherent radiating aperture
  - The aperture has max dimension of D = 15 cm
  - The aperture can be placed anywhere within the QZ
- In this situation, the following requirement on test zone quality applies:
  - A magnitude <u>and</u> phase requirement on test zone quality is sufficient.

02 5G OTA Test Methods

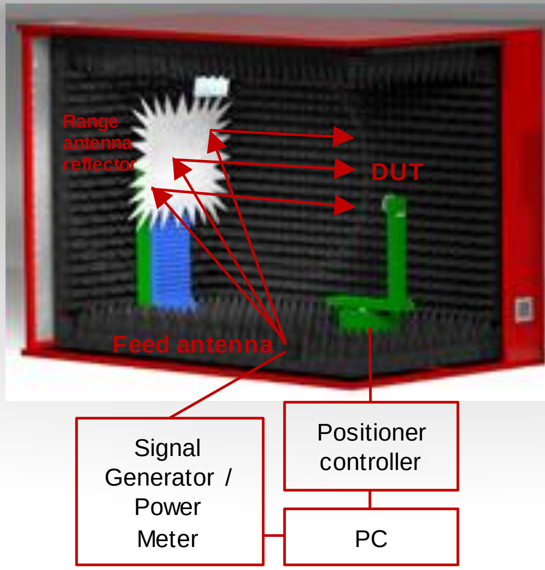
5G FR2 OTA Test Methods

- **Direct far field (DFF) method:**
  - A classical OTA system with measurement and link antenna(s) placed displaced by $2D^2/\lambda$ from the center of the QZ.





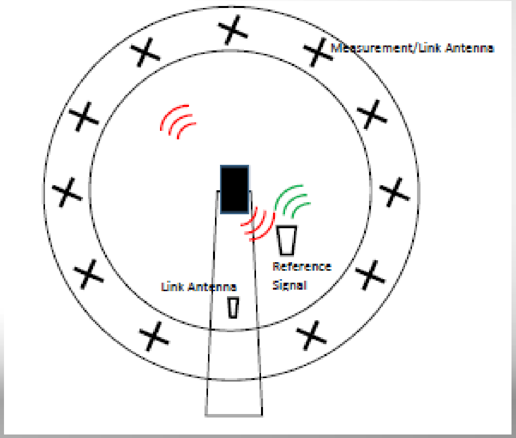
- **Indirect far field (IFF) method:**
  - It creates the far field environment using a transformation with a parabolic reflector (CATR) or two-dimensional antenna array (PWC).



02 5G OTA Test Methods

5G FR2 OTA Test Methods

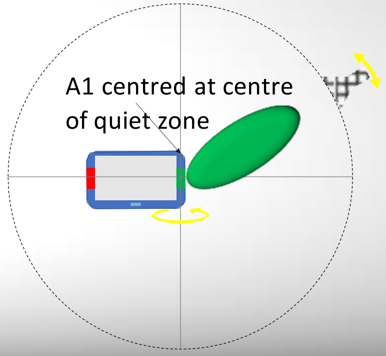
- **Near field to far field transform (NFTF) method:**
  - Method that is using a mathematical transform to determine EIRP in the far field from a near-field pattern scan.
- **Near-field without near-field to far-field transform (NFWOTF) method:**
  - Method that is using measurements performed in the radiative near field without the use of a near-field to far-field transform.
- **Reverberation Chamber (RC) method:**
  - A typical reverberation chamber with a link antenna positioning system for initial beam steering purposes.



02 5G OTA Test Methods

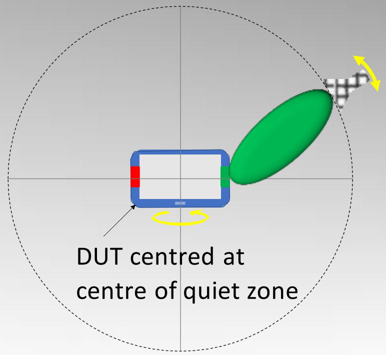
White Box vs Black Box Testing

- For the “white box” approach, the exact antenna locations need to be known, likely via a manufacturer declaration:
  - The active antenna array needs to be aligned with the center of the quiet zone which likely yields complex execution of test cases.
  - An MU element for “Offset DUT phase center from center of QZ” will not need to be added for the DUT stage but a MU element for UE re-positioning needs to be added.



Selected in RAN4

- For the "black box” approach, the exact antenna locations do not need to be known:
  - The UE is positioned with a common reference point similar to existing SISO OTA test cases.
  - Execution of test cases have relatively low complexity (repositioning will not be necessary).
  - An MU element for “Offset DUT phase center from center of QZ” will need to be added for the DUT stage of the MU budget which depends on size of QZ, and range length.



02 5G OTA Test Methods

Far-Field OTA methods

- DFF may be impractical due to the required far-field range *R*, specially when assuming that the size of the radiating elements matches the device size ("black box" approach):

***D* [cm]**	***R* [m]**	
	@24.25GHz	**@43.5GHz**
2	0.1	0.1
5	0.4	0.7
10	1.6	2.9
15	3.6	6.5
20	6.5	11.6
30	14.6	26.1
40	25.9	46.4
50	40.4	72.6

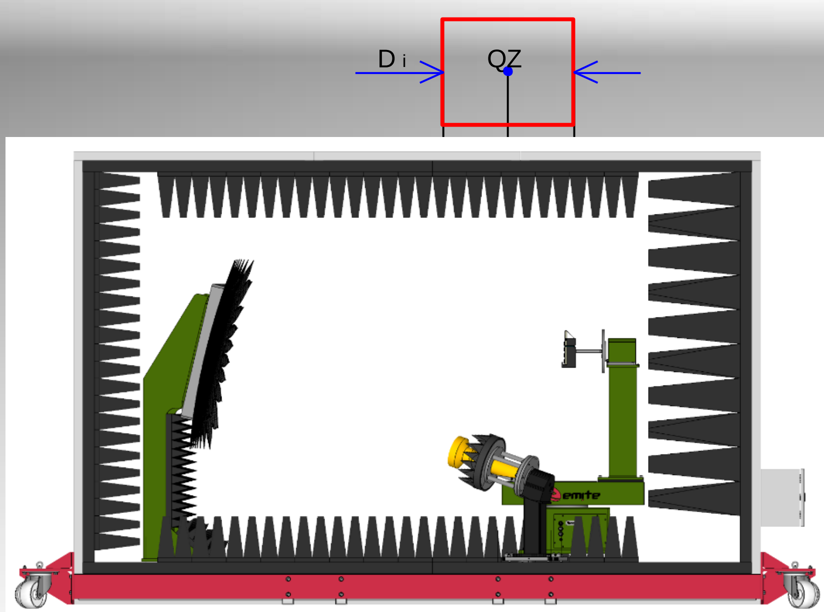
$$R > \frac{2D^2}{\lambda}$$

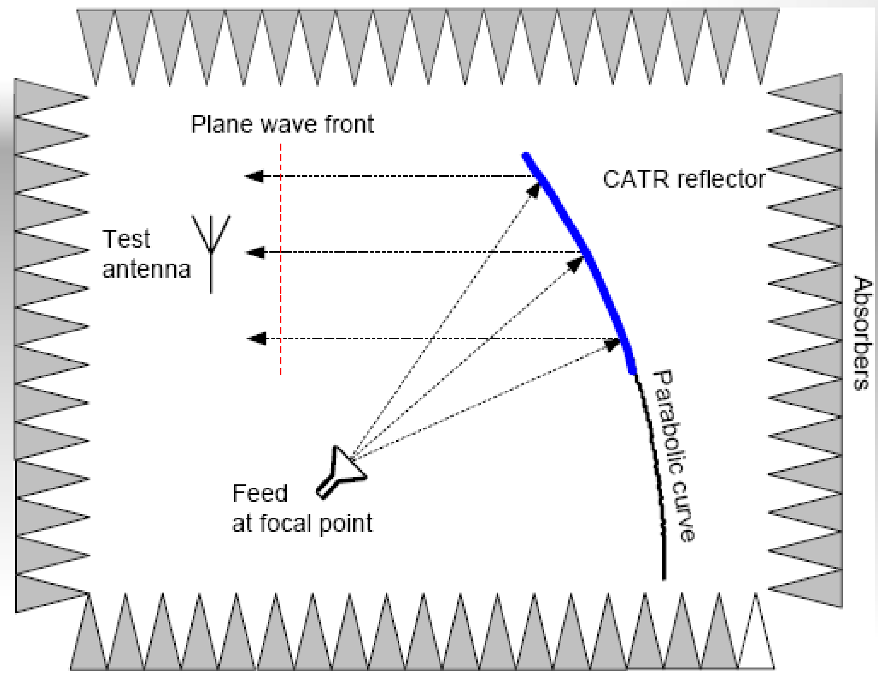
- Note that in most cases it is expected that the radiating performance of array antennas will be limited to the region around the antenna.
- Thus, the "black box" approach supposes an over estimate for the vast majority of antenna arrays (other than sparse antenna arrays).

02 5G OTA Test Methods

Far-Field OTA methods

- Indirect far field (IFF) method:
  - Compact Antenna Test Range (CATR):
    - The fed spherical wave is transformed in plane wave within the desired quiet zone (QZ):



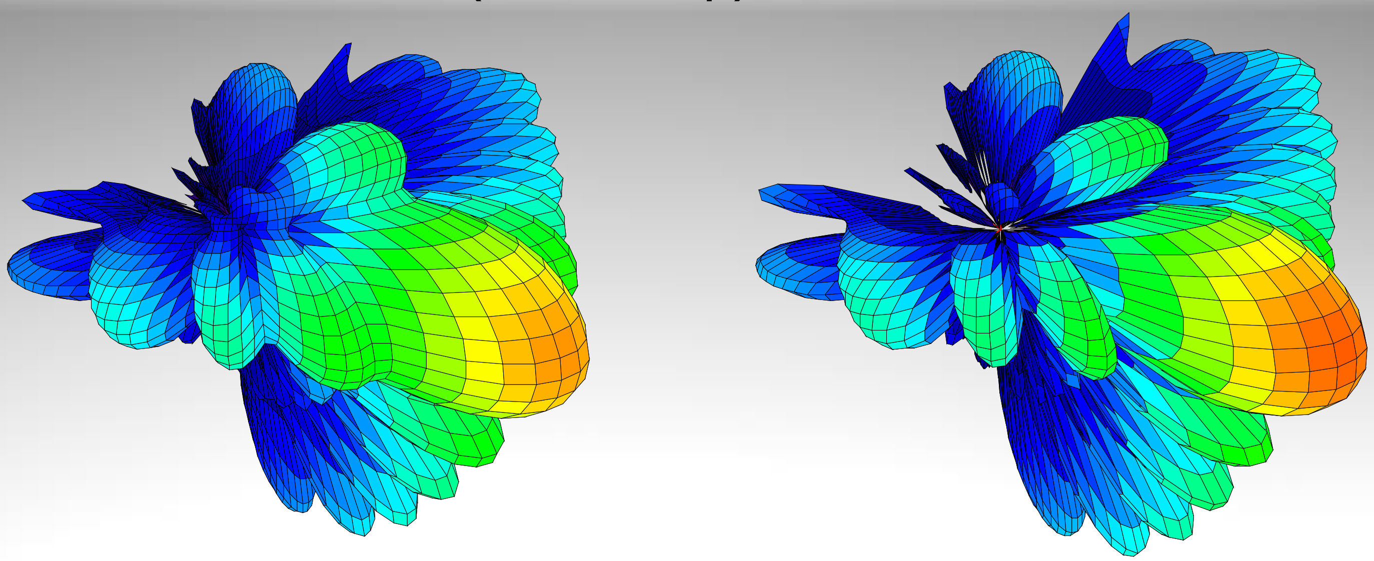


02 5G OTA Test Methods

Near-Field OTA methods

- At near-field distances (as with a NFWOTF setup), the beamformed antenna pattern will not be equivalent to what the user will see in the far field.
  - Nulls are not so deep.
  - Pattern is smoother (less sharp).

Near Field



Far Field

02 5G OTA Test Methods

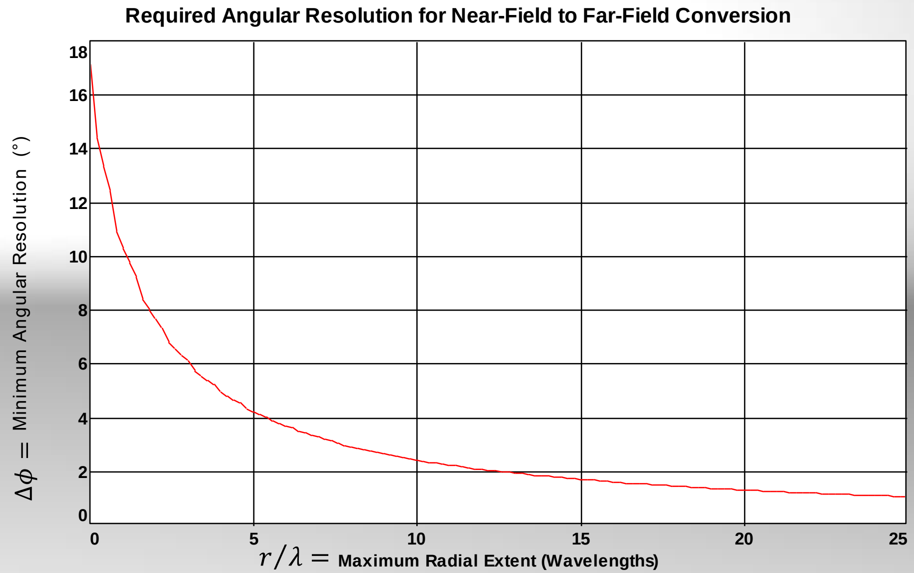
Near-Field OTA methods

- NFTF method may be an alternative, but:
  - It requires high resolution scans across the majority of the pattern to accurately predict the far field:
    - Maximum Radial Extent: $r = \frac{D}{2}$
    - Minimum Angular Resulution:

$$\Delta\phi = \frac{\pi}{M} = \frac{\pi}{kr+N} = \frac{\pi}{\frac{2\pi r}{\lambda}+N}\ \text{rad} =$$

$$= \frac{180}{2\pi\frac{r}{\lambda}+N}\ \text{degrees}$$

    - E.g.: $N = 10$



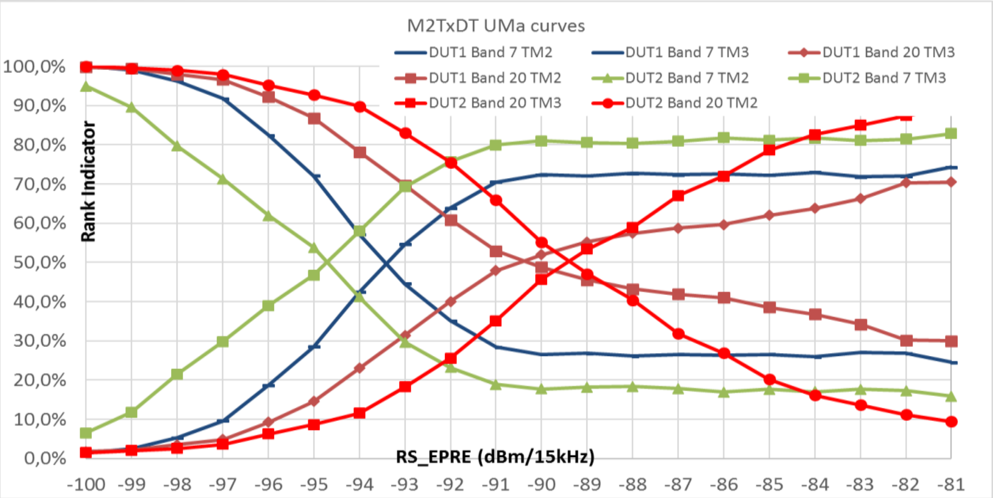
Source: J. Hald, J. E. Hansen, F. Jensen, and F. Holm Larsen, *Spherical Near-Field Antenna Measurements*, ser. IEE electromagnetic waves series, J. Hansen, Ed. Peter Peregrinus Ltd., 1998, vol. 26, edited by J.E. Hansen.

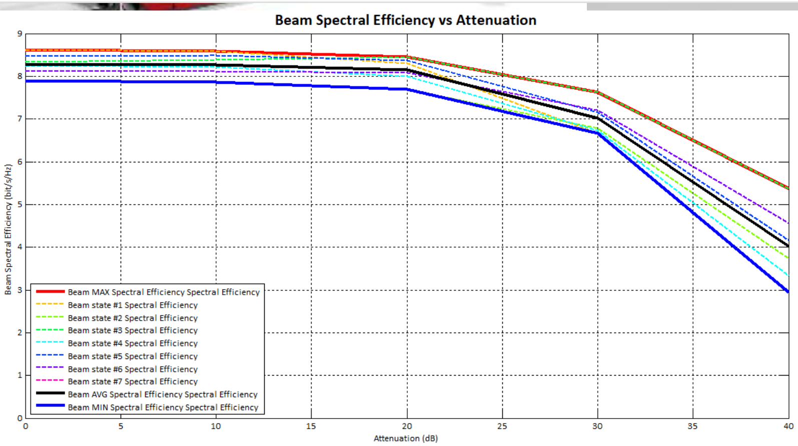
  - It becomes problematic for active device testing.

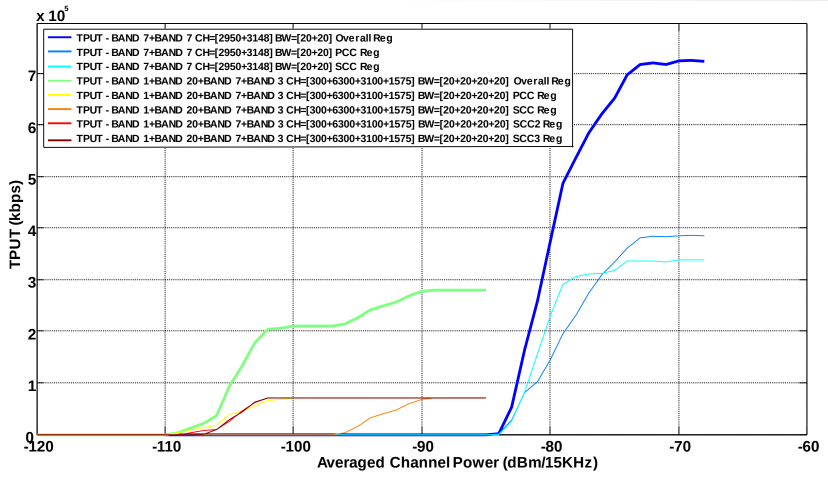
02 5G OTA Test Methods

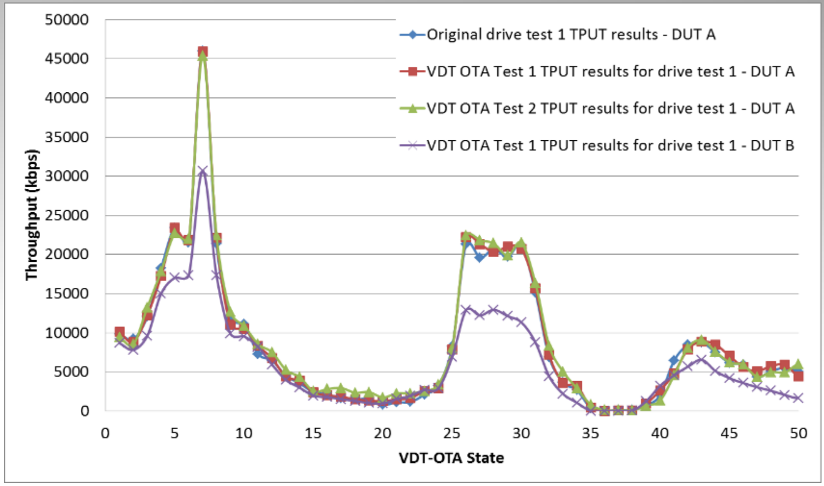
Reverberation OTA methods

3D-averaged KPIs





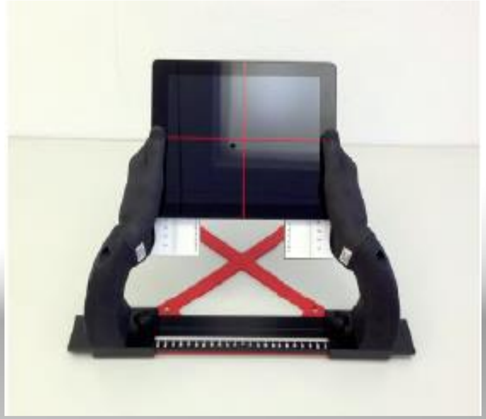




02 5G OTA Test Methods

Reverberation OTA methods

Large Quiet Zones

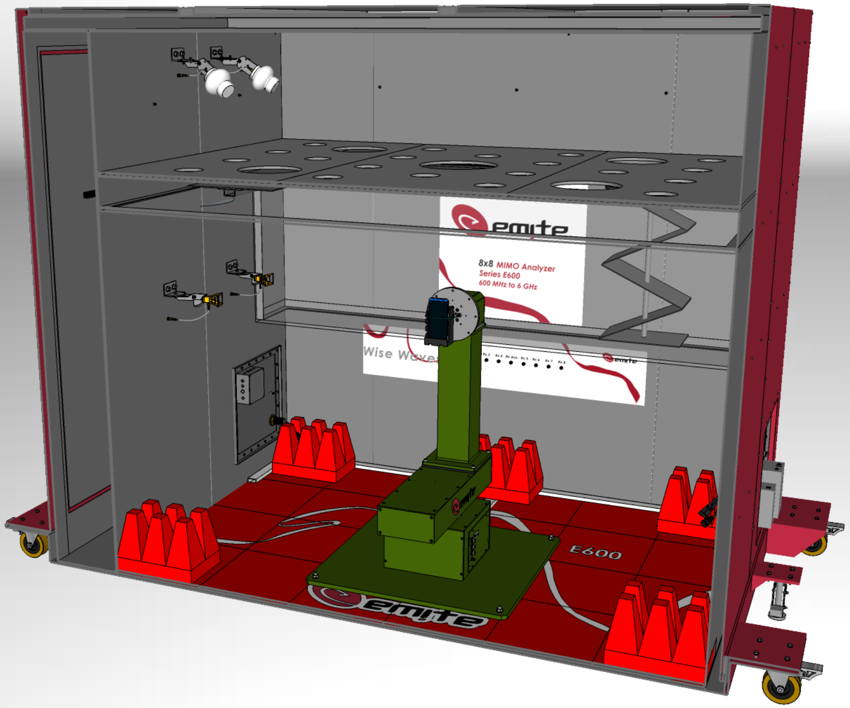


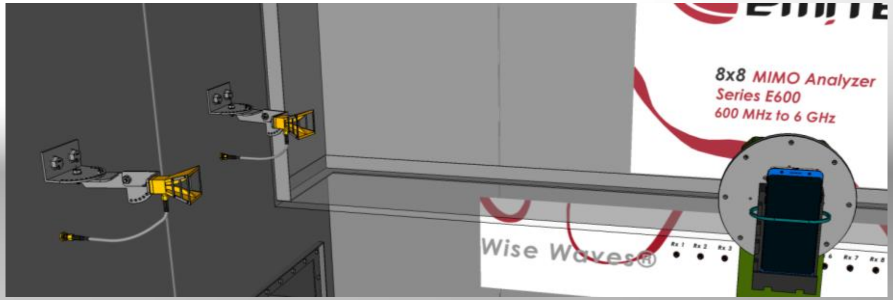
CPEs

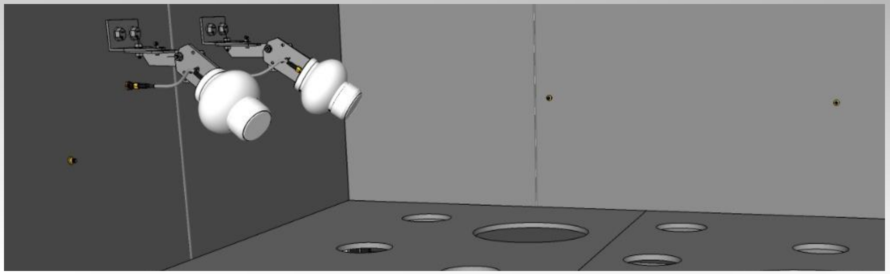
02 5G OTA Test Methods

Reverberation OTA methods

FR1+FR2





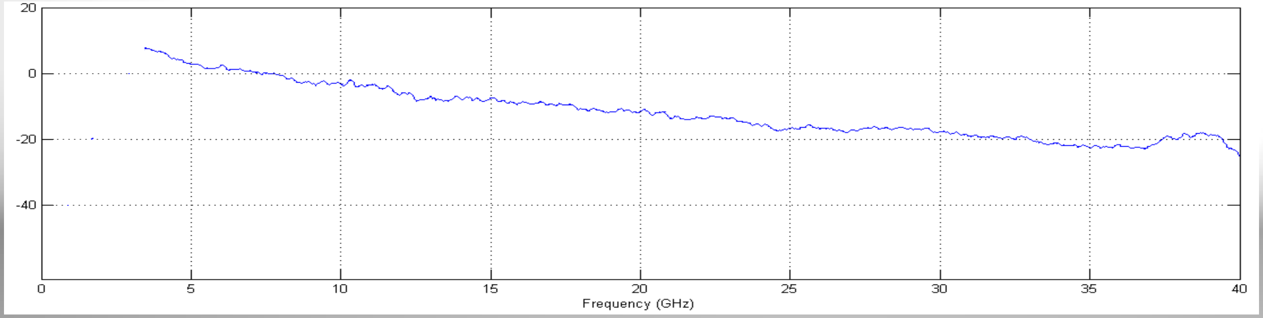


02 5G OTA Test Methods

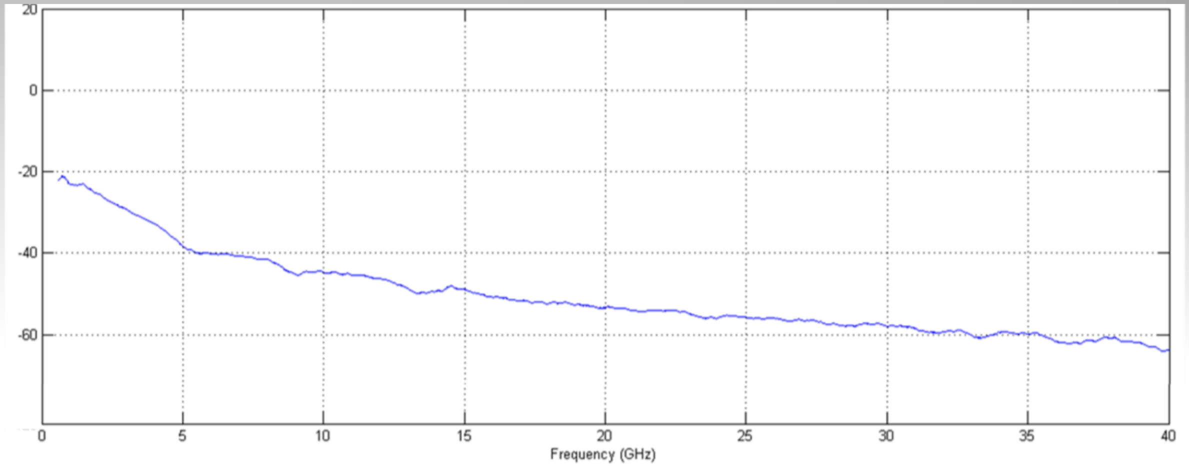
Reverberation OTA methods

FR1+FR2

LoS Path Loss (dB)

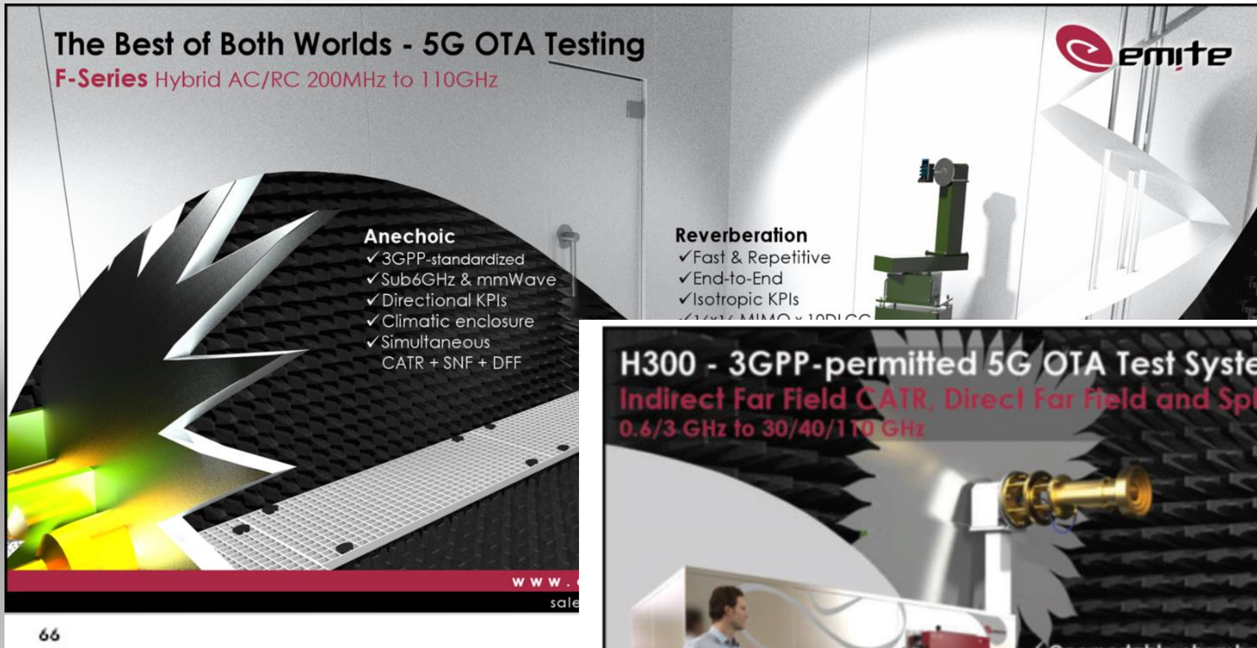


NIST Path Loss (dB)



02 5G OTA Test Methods

Hybrid OTA methods



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03 Challenges for 5G OTA Testing

Frequency Spectrum

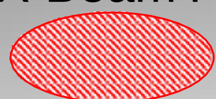
Mapping KPIs to FR2

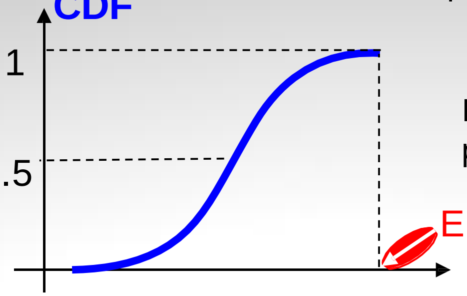
- TRP → EIRP, TRP, Spherical Coverage/EIRP CDF:
  - UE Maximum Output Power Tests are performed in the TX Beam Peak direction:
    - EIRP will have a minimum requirement for power class.
    - EIRP has a maximum requirement (from regulatory requirements).
    - TRP is TBD.
  - The spherical coverage test will determine EIRPs in 3D to create a CDF curve:
    - A 50%-tile requirement for EIRP CDF is TBD.
- TIS/TRS → EIS:
  - REFSENS tests will be performed in the RX Beam Peak direction.

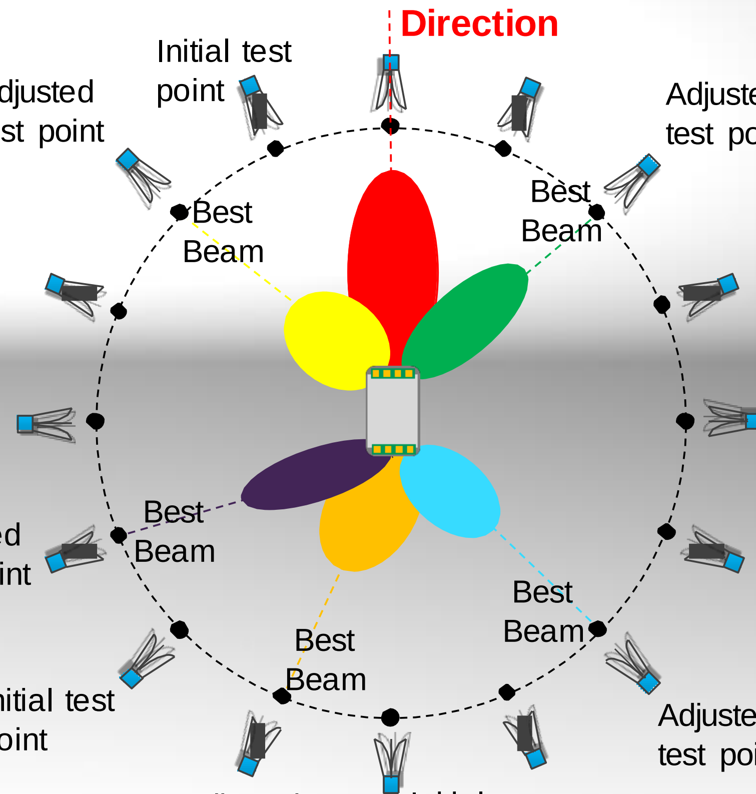
03 Challenges for 5G OTA Testing

Frequency Spectrum

Mapping KPIs to FR2

- Key Performance Indicators (KPIs):
  - EIRP @ TX Beam Peak Direction  EIRP$_{Peak}$
  - TRP @ TX Beam Peak Direction  TRP
  - Spherical Coverage/CDF of EIRPs





03 Challenges for 5G OTA Testing

Frequency Spectrum

Applicability Criteria

- Each permitted method had to provide an applicability statement:

Method	Vendor declaration of antenna size needed	EIRP	TRP	Test Metric		RSE	IBB
				EIS	EVM		
DFF	yes	yes	yes	yes	yes	yes	yes
IFF	no	yes	yes	yes	yes	yes	yes
NFTF	yes	yes	yes	no	no	yes	no
NFWOTF*	yes	partial †	yes	no	no	yes	no
RC*	yes	no	yes	no	no	yes	no

* Not a permitted method yet
† EIRP can be used only for TRP fallback (RSE)

03 Challenges for 5G OTA Testing

Frequency Spectrum

*Measurement Uncertainty (MU)**

KPI \ setup	DFF (D = 5 cm)	IFF (D = 15 cm)	NFTF (D = 5 cm)	NFWOTF (D = 5 cm)	RC (D = 5 cm)
EIRP Expanded uncertainty (1.96σ - confidence interval of 95 %) [dB]	[6.20]	[5.99]	[5.92]	[5.93]	[6.76]
TRP Expanded uncertainty (1.96σ - confidence interval of 95 %) [dB]	[5.37]	[5.13]	[5.04]	[5.47]	[6.01]
EIS Expanded uncertainty (1.96σ - confidence interval of 95 %) [dB]	[6.66]	[6.49]	N/A	N/A	[7.20]

- ✓ **Fading at mm-Waves**
- ✓ **Differenty antenna sizes**
- ✓ **KPI mapping**
- ✓ **3D channels**
- ✓ **Band combinations**

* RAN5 agreed to continue the MU analyses

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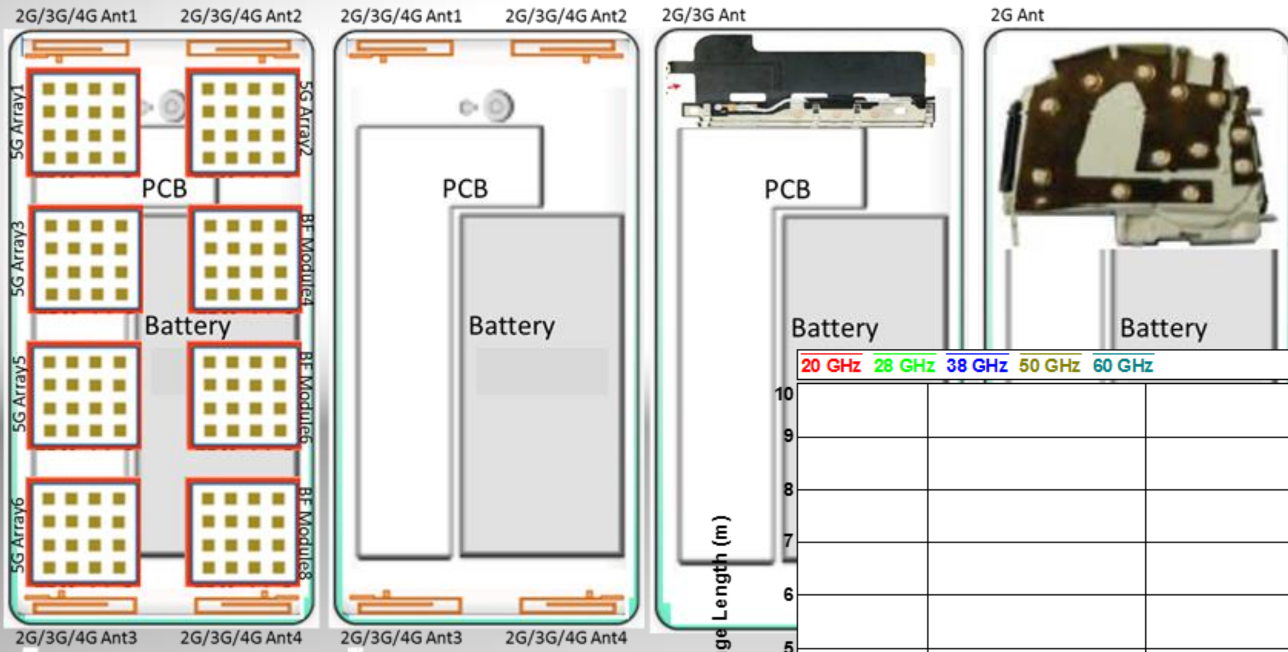
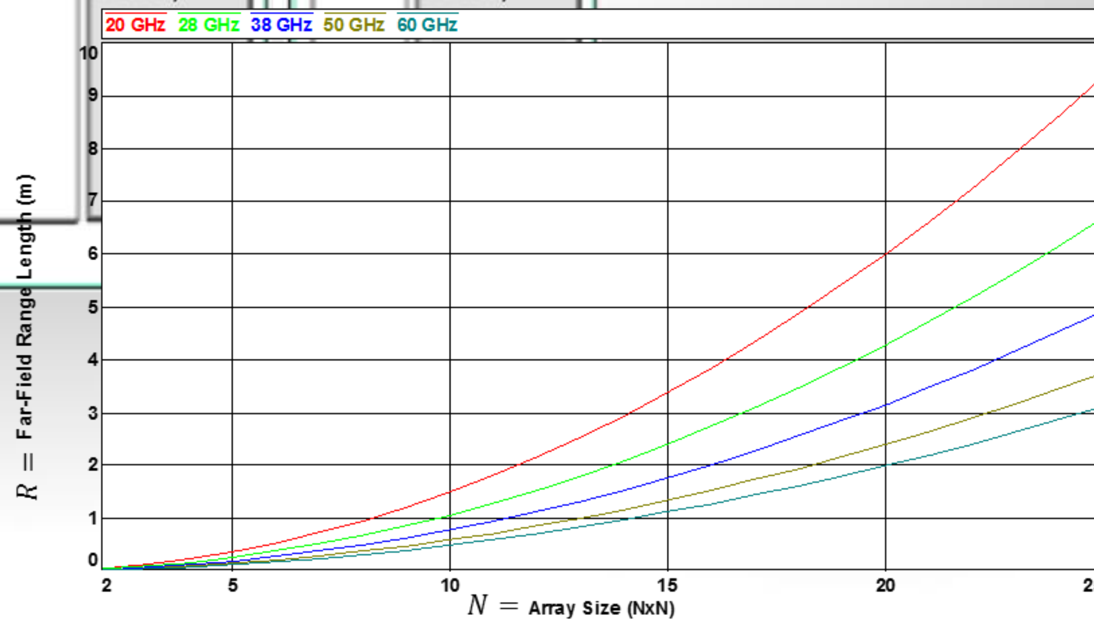
03 Challenges for 5G OTA Testing

Fully-integrated Antenna Arrays





- ✓ **Phase calibration**
- ✓ **Coupling**
- ✓ **Heating**

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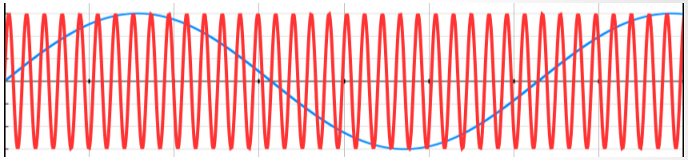
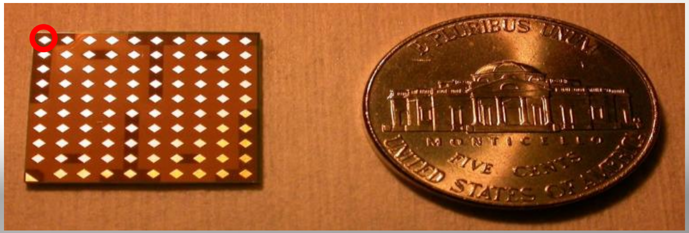
03 Challenges for 5G OTA Testing

DUT Form Factors

- Comparing 2 GHz vs 60 GHz…
  - 150 mm wavelength becomes 5 mm.
- Individual antenna size is much smaller in mmWave.





Source: IBM and Ericsson

- ✓ **Black box testing**
- ✓ **Cooling**
- ✓ **Relative size to wavelength**

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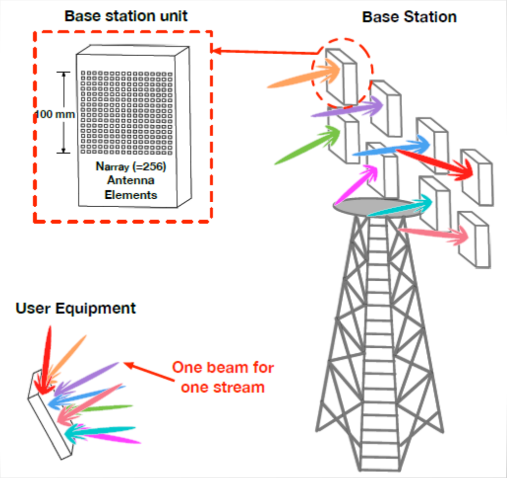
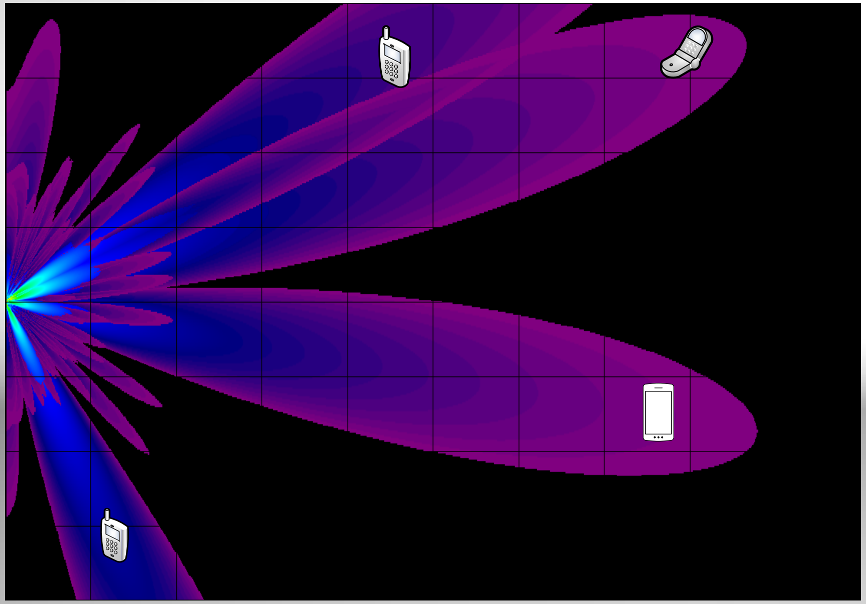
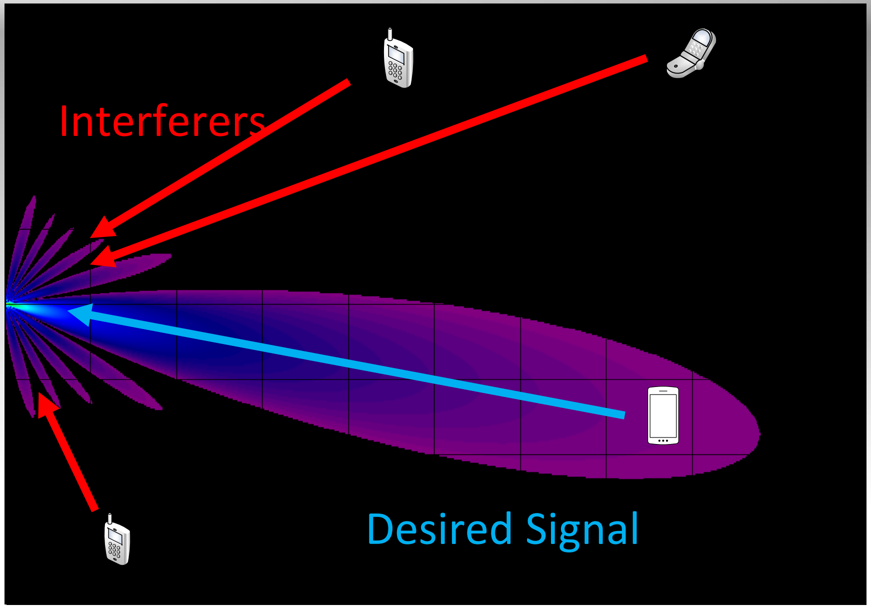
03 Challenges for 5G OTA Testing



Spatial Agility



- ✓ **Beam tracking delays**
- ✓ **Beam assignment**
- ✓ **Beam refinement**
- ✓ **Non-optimum condition**



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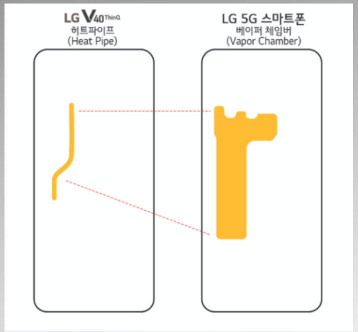
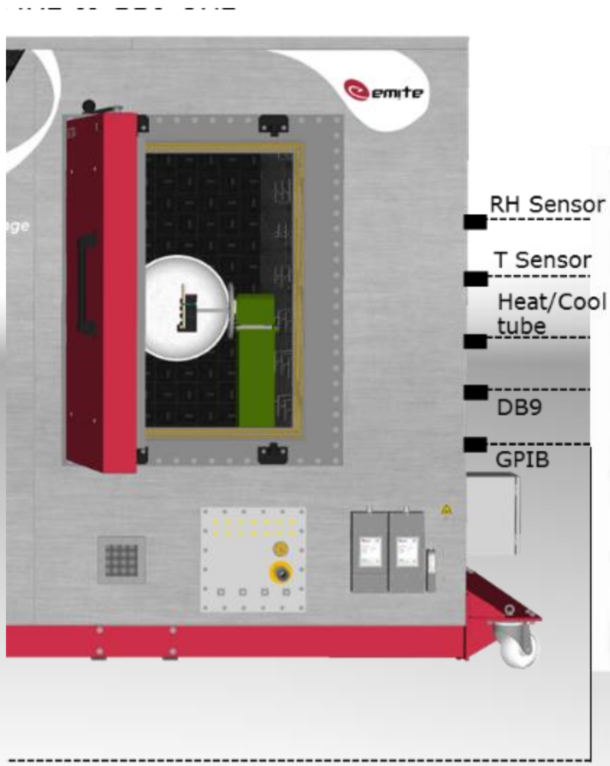
03 Challenges for 5G OTA Testing

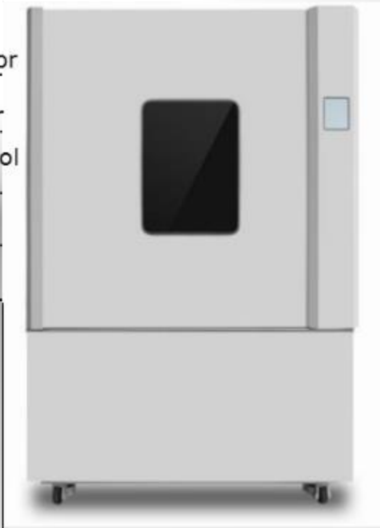
Climatic Conditions

hTC 5G Hub

LG V50 ThinQ







- ✓ **Heat dissipation**
- ✓ **Humidity control**

Wise Waves
MIMO Measurements
Made Simple

emite

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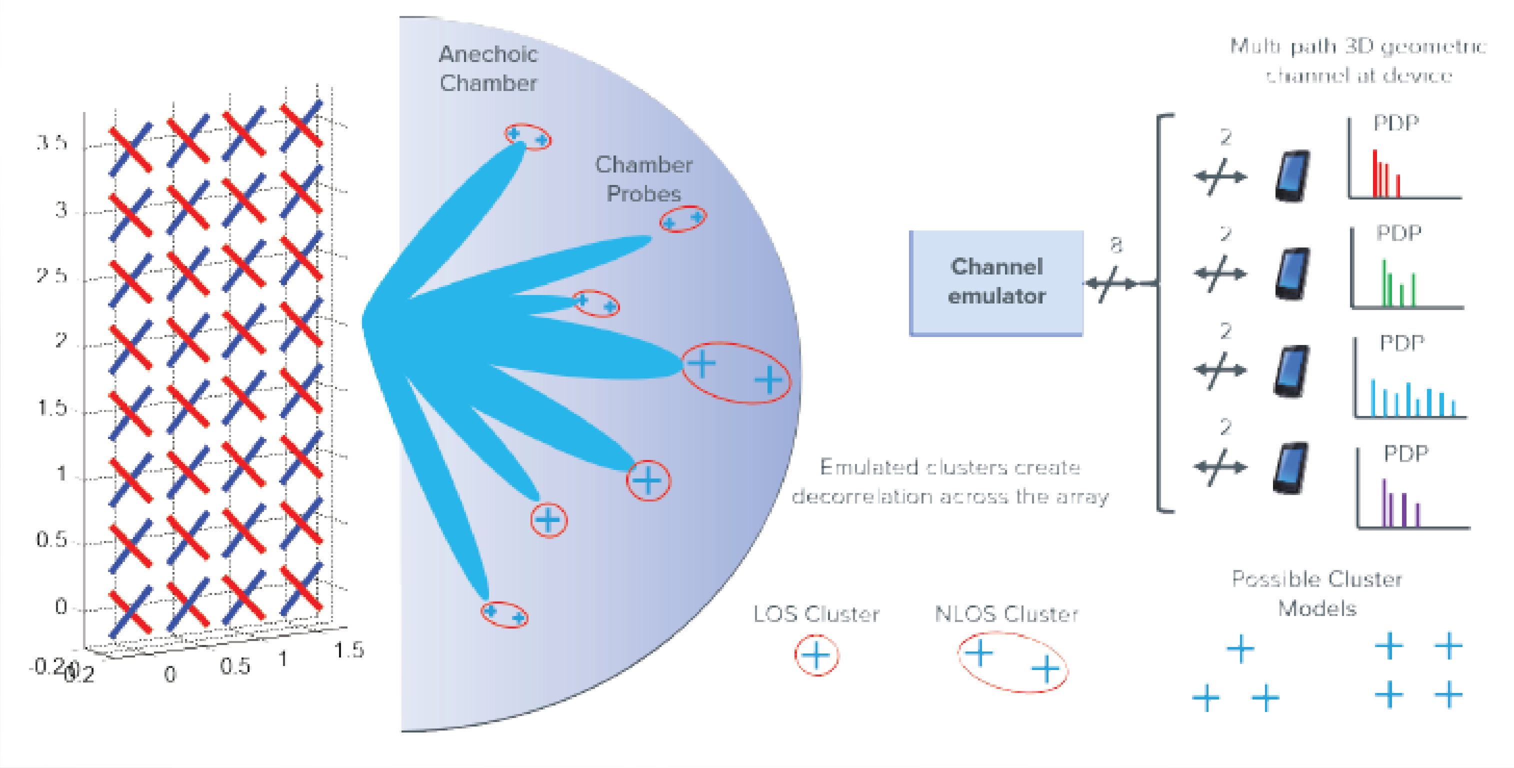
03 Challenges for 5G OTA Testing

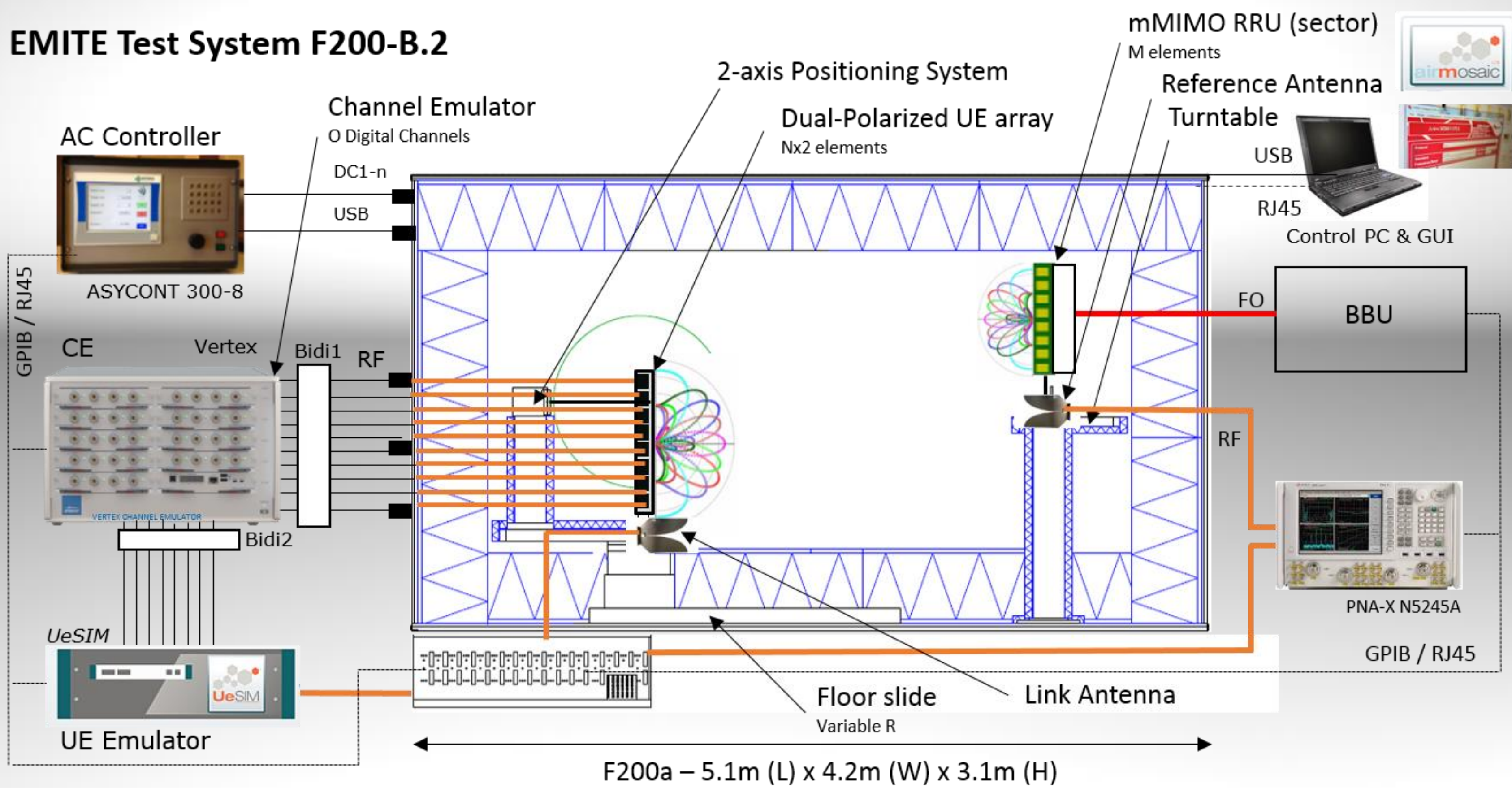
Channel Modeling



* By Spirent

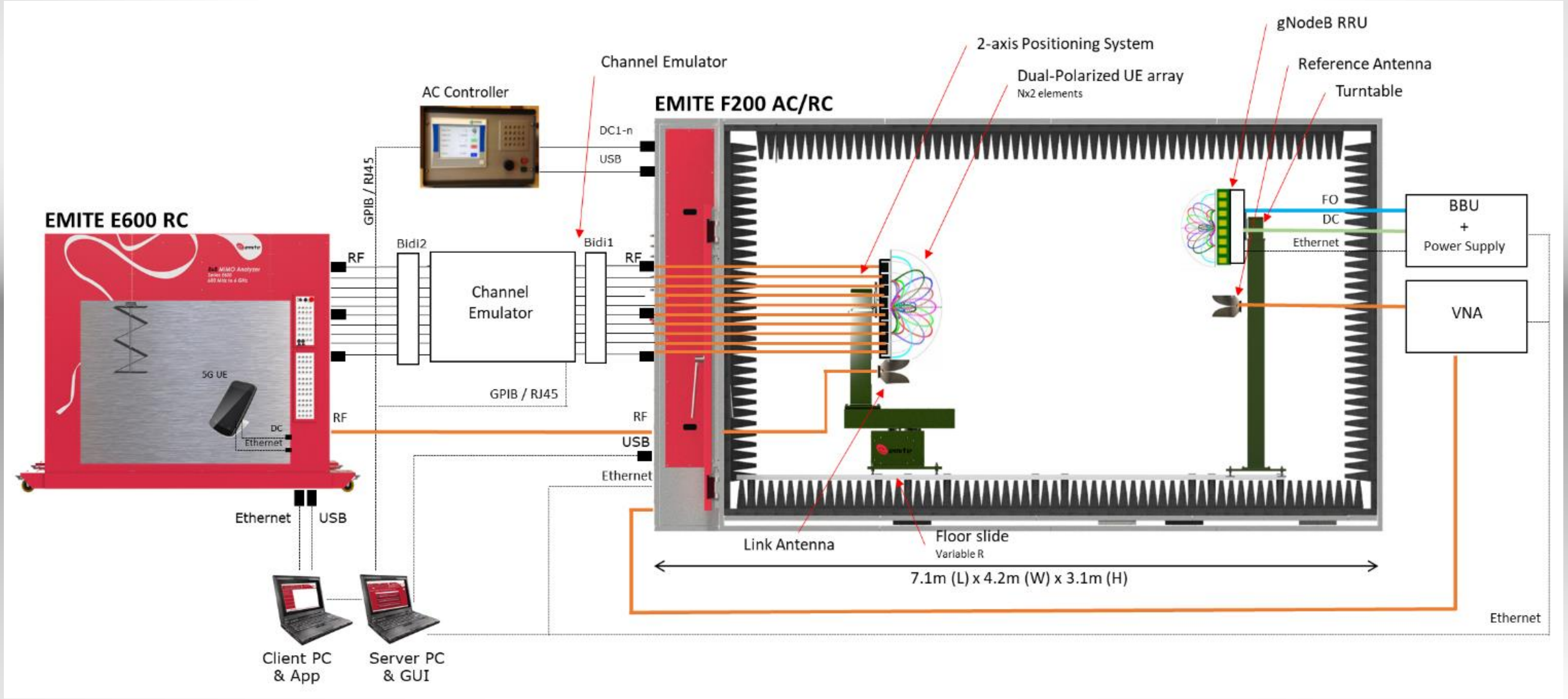
03 Challenges for 5G OTA Testing

Channel Modeling



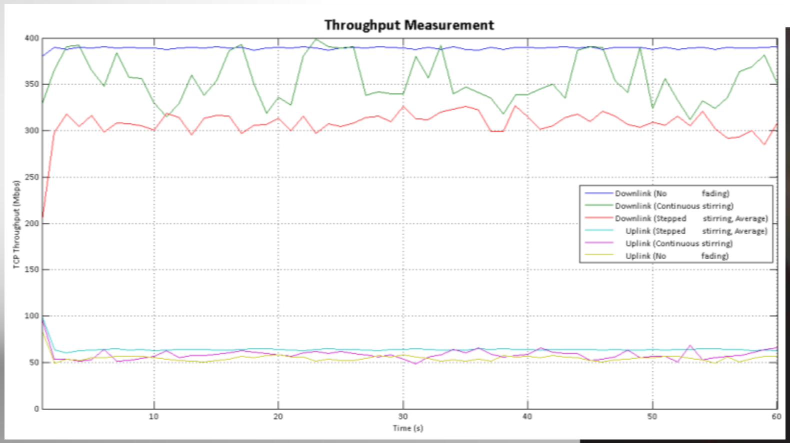
03 Challenges for 5G OTA Testing

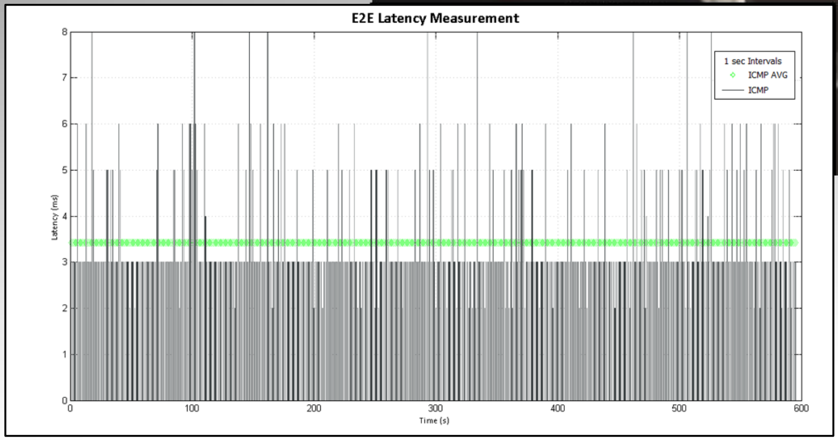
Channel Modeling



03 Challenges for 5G OTA Testing

Channel Modeling



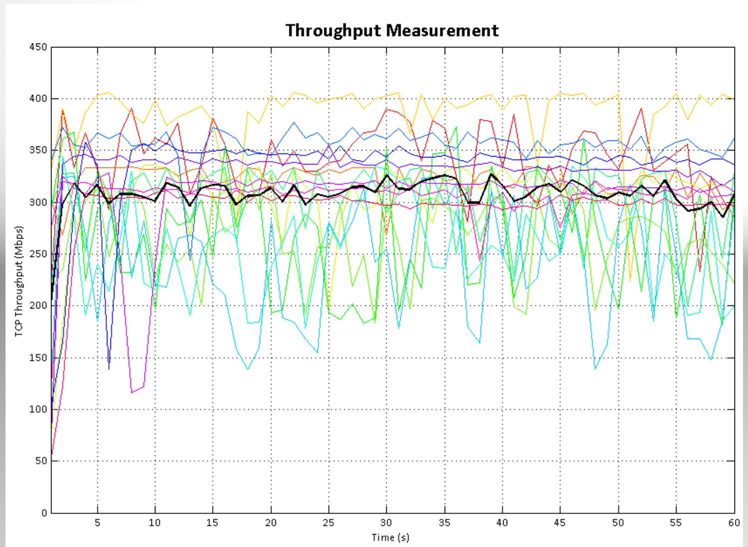


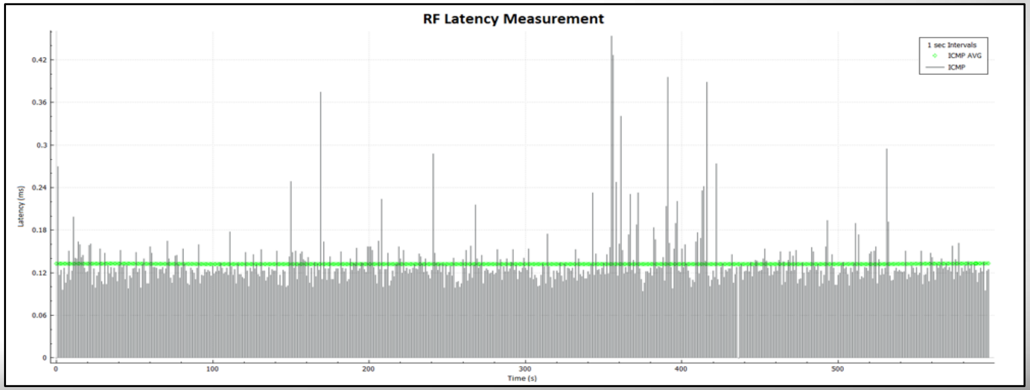
5G SA OTA testing with fading

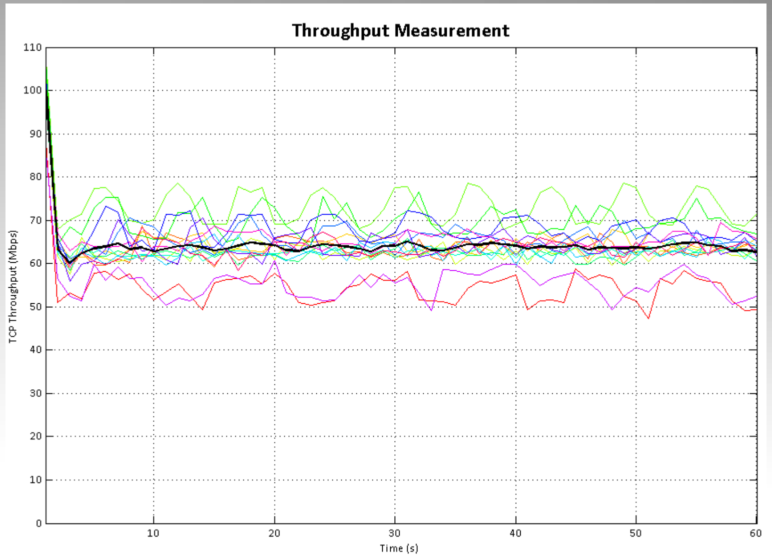
Worldwide-first

03 Challenges for 5G OTA Testing

Channel Modeling







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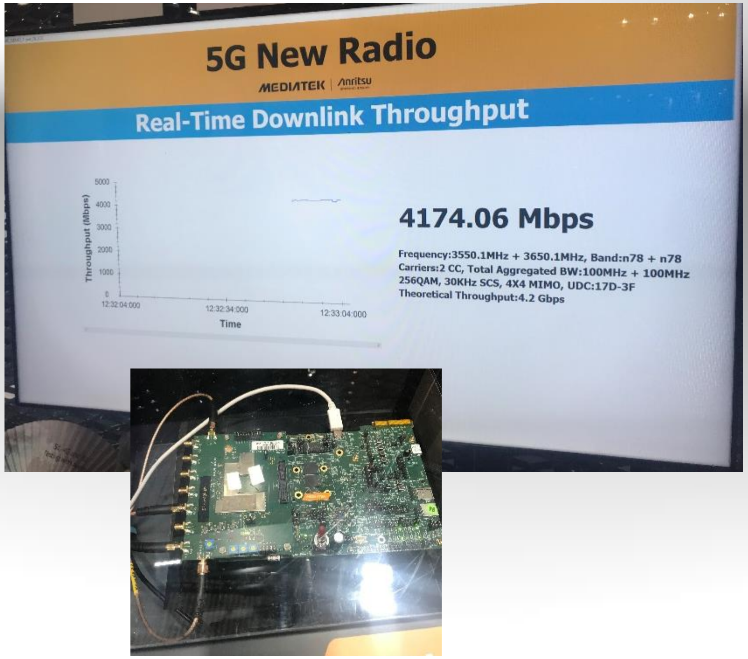
04 Conclusions

- ✓ **5G brings unheard-off benefits and challenges**
- ✓ **Complex test set-ups, even for single-user test cases**
- ✓ **Additional UE requirements: Cooling, FR1+FR2, relative size to λ**
- ✓ **Hybridization of OTA Test methods**
- ✓ **Elaborated mMIMO Figures of Merit**
- ✓ **Standardization behind schedule**
- ✓ **5G network deployment is here**
- ✓ **A lot of work to be done, with literally no time**



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Thank you for your attention.